Pest Management Grants Final Report

Contract No. 98-0283

Plug Plant and Soil Amendment Technology as Alternatives to Methyl Bromide Fumigation on California Strawberries

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Disclaimer

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Abstract

Three strawberry soil management systems were tested with conventional bare root plants and alternative plug plants and under field conditions. The soil treatment systems included an organically acceptable non-chemical system using high rates of compost and other soil amendments, two alternative soil fumigants, Telone/chloropicrin and Iodomethane/chloropicrin, and a methyl bromide chloropicrin standard system. The highest yielding soil system was the alternative program using Telone/CP and Iodomethane /CP. With respect to plant type, plug plants out-yielded bare root plants in all soil management systems, with yield increases ranging from 141.5 to 164.9 percent higher seasonal yields than conventional bare root technology. Actual yields for these programs for the duration of harvests were as follows: Organic bare root plots yielded 15050 kg/ha, Organic plug plant system at 37510 kg/ha. The Alternative plots with Telone/CP planted to bare roots yielded 16348 kg/ha, compared to Telone/CP plug plants at 43306 kg/ha. Iodomethane/CP planted to bare root plants yielded 16968 kg/ha, compared to 40439 kg/ha for Iodomethane planted to plugs. The conventional standard methyl bromide/CP bare root program yielded 15024 kg/ha compared to methyl bromide/CP plugs at 36291 kg/ha. In addition to higher yields, plug plants had significantly fewer runners than bare root plants late season.

Executive Summary

Full season study, 1999-2000: Three strawberry soil management systems were studied for overall plant performance, production costs and seasonal fruit yields. Each production system comprised statistical main plots that were replicated three times in Latin square fashion. The first was an organic system that was not fumigated and instead used 56T/ha compost and Mycorrhizal root treatment prior to planting. The second system used alternative fumigants Telone/chloropicrin C35 at 393 kg/ha , and Iodomethane (methyl iodide)/chloropicrin 75/25 at 393 kg/ha as drip applied preplant soil fumigants; and the third was methyl bromide/chloropicrin 75/25 soil fumigant broadcast at 393 kg/ha as the commercial standard. Half of each of these four soil treatments were planted with conventional bare root Camerosa low elevation plants, and the other in Camerosa plug plants produced on the central California coast. Telone and Iodomethane/CD were fully comparable, and numerically superior to methyl bromide/chloropicrin. The organic system was the lowest yielding of any soil management system studied. Throughout the season, plug plants were the highest yielding plant type across all four-soil treatments. Total seasonal yields by soil system and plant type were as follows: Organic bare root 15050 kg/ha, Organic plug 37510 kg/ha, Telone/chloropicrin bare root 16348 kg/ha, Telone/CD plug 43306 kg/ha, Iodomethane bare root 16968 kg/ha, Iodomethane plug 40439 kg/ha, and methyl bromide standard bare root 15024 kg/ha, and methyl bromide plug 36291 kg/ha. Weed control data did not demonstrate differences between treatments, since all production systems used opaque plastic to limit weed development. In addition to higher yields, plug plants had significantly fewer runners produced late season, which gives further advantage to the plug plant production system. These results support previous data by this author, and demonstrate significant advantages of this technology for utilization by California growers.

Outreach: At the initiation of this project, a "Methyl Bromide Alternatives Workshop" was held at the Pacific Ag farm in San Luis Obispo in the fall of, 1998. This meeting was attended by over 100 PCA's, growers and other interested persons on the central coast. Five DPR continuing education credits were given for this event

Introduction

This project evaluates alternative production systems for California strawberries. These data present the fifth year of field tests of alternative chemical fumigation, greenhouse grown strawberry plug plants, and an organically acceptable production program with potential use to a wide variety of California growers.

Previous data has indicated that land with a history of fumigation with methyl bromide may require several years of organic management to rebuild populations of soil microbes to levels that will sustain organic production. Conversely, pasture, permanently cover-cropped, or otherwise unfarmed land can have a highly diverse soil food web that could sustain strawberry production and potentially be suppressive to low levels of plant pathogenic organisms well into the season. Land fallowed or not previously cultivated, however, can have large reservoirs of weed seeds that increase production costs in organic culture if not treated aggressively. In addition, successive years of strawberry culture on non-fumigated land could increase strawberry root pathogens to the extent that organic production techniques are no longer effective. Under these conditions, soil fumigation can manage both weed populations and root pathogens, and allow farming these fields again to be profitable. Organic methods may only be utilized in these cases when the soil is frequently rotated to non-host or disease suppressive plants such as *Brassica* spp.

This project was undertaken to further develop improved strawberry transplant technology in conventional and alternative production systems. Previous data by this author have shown significant yield increases in non-fumigated soil with the use of plug plants, in which may provide an alternative to methyl bromide fumigation for strawberries in the future.

Materials & Methods

The site for this study was a one-acre field that was pastured for 26 years, cover-cropped for one year, and then planted to lettuce prior to the strawberry treatments reported here. The soil had no previous history of soil fumigation. In the preceding lettuce crop, the soil was managed according to three regimes: Conventional, Alternative, and Organic (see Appendix 1). These replicated blocks were located in the same field areas that the strawberry production systems reported here were to be placed in the fall. In this lettuce study, Conventional blocks received 500 lbs/ac 15-15-15 pre-plant, followed by two 30 gallon/ac applications of AN20 (ammonium nitrate solution) totaling approximately 174 K/ha N. The alternative plots received short seåson controlled release Agriform® 19-6-12 fertilizer at 916 K/ha (matching the N usage of the conventional plots). The organic blocks received 20 T/ac compost preplant, followed by applications of fish emulsion (10 gal/ac) at two week intervals through the drip irrigation system. The lettuce study concluded in August following harvest data collection. The field was prepared for strawberries as follows:

1. Soil was plowed to 30 cm. and triple disked to the same depth, and overhead irrigated periodically for two weeks (approx. 10 cm water applied).
2. In the three methyl bromide fumigation main plots, 75/25-methyl bromide/chloropicrin was injected to a 30 cm depth and immediately covered with tarp by the commercial contractor. In the organic blocks, 25 T/ac of high quality compost and 500 lb of palletized and composted chicken manure were broadcast applied and incorporated to a 10 cm depth. At planting, plants in these plots received mycorrhizae inoculate at 3 gm/plant (Mycor root inoculate, Ecogen Corp. Langhorne, PA).
3. After one week, the plastic tarp was removed and beds were listed to 50 cm. (20 in.) in depth at 99 cm (40 in.) centers.
4. These beds were then shaped and drip irrigation and fertilizer applied. In both the alternative and conventional blocks, Agriform® 16-6-12 Long Season fertilizer was applied at a rate of 1123 kg/ha (1000 lb/ac.)
5. In the Alternative plots, planting beds were covered with VIF film and secured on the sides with additional soil to obtain a uniform seal. Soil fumigant treatments were then drip applied to four subplots within the main plots. Two plots (one for bare root and the other for plug plants) received iodomethane/chloropicrin 75/25 at 393 kg/ha, and the other two received Telone®/chloropicrin C-35 at 393 kg/ha.
6. A week after the drip treatments were applied, the plastic was removed and beds aerated for one week.
7. All beds were then covered with conventional black plastic and main plots separated by ditch breaks a across beds. Between adjacent plots lengthwise, single row buffers were planted to a beneficial insect mixed species cover crop. (See color plate 1).
8. Twenty-one days after rows were drip fumigated in the alternative block, plastic row mulch was perforated and planted as follows:

a) Bare root plants were set 35 cm (14 in.) apart within rows and pressed in to eliminate air spaces in root zones. Six beds per main block were planted to bare root Camarosa daughter plants. In the Organic plots, all bare root plants were dipped in a dry formulation of mycorrhizae (Mycor @ 3 gm.plant, Ecogen Inc. Langhorn, PA) prior to planting.

b) The remaining six rows in each main plot were planted in Camarosa plug plants. In these plots, plants were similarly dipped in mycorrhizae inoculate prior to planting.

9. Plots were watered by sprinkler irrigation for three weeks until sufficiently set.
10. In the organic plots, sprinklers were removed and wheat straw was placed into furrows for weed control after sprinklers were removed at a rate of approximately 1 kg/m of furrow (4 bales/300 ft. furrow).
11. All plots were separated by a single buffer row of beneficial insect mix (approx. equal parts Alyssum, clover, vetch, California poppy, purple thistle, bachelor button, L.A. Hearne Co. King City, CA). This cover crop mix was also planted at row ends. This resulted in each 12 bed by 30 m (100 ft) plot being framed by buffers planted in beneficial insect mix.
12. All plots were grown to maturity, weeded, irrigated as required, and harvest commenced on March 30, 2000. Weekly fruit yields were segregated into US No. 1 and second quality, and flats were counted and weighed. Fruit size was determined by weighing 20 representative fruit per plot, dividing the total weight by 20, yielding average grams per fruit. Commencing with the harvest on June 27, all fruit was harvested as per processing market. This involved bulk-packed fruit that was harvested by weight only.
13. Late season, the soil was again sampled for biomass determination by coring 20 subsamples per plot and submitting them for analysis at Soil Foodweb, Inc. Corvalis Oregon. Runner production per plant was also ascertained by directly counting daughter plants from 10 plants randomly selected mother plants per plot.

Results

Crop Development

Data for crop development parameters measured are presented in Table 1 below. Early season, flower and leaf number were determined on February 24. Neither parameter consistently favored any one treatment or plant type. Telone/CP had significantly fewer flowers in the plug plant plots on the week sampled, but this early season trend did not manifest itself in lower overall season yields. Plant growth was similar between plant types, including leaf number and resulting plant diameters. Late season development however, revealed differences in runner production between plug and bare root plants. In this study, runner production did not occur to the extent that it did in conventional bare root plants, These data show a 63% reduction in runner production in the organic production system, a 93% reduction in runner production in the Telone/CP production system, a 92% reduction in the iodomethane system, and a 58% reduction in the methyl bromide standard production system. While other aspects of crop development were similar between plant types, this trend in runner production was highly significant and consistent among all soil fumigation treatments.

Table 1. Selected strawberry plant development parameters early and late season in 4 soil management and two transplant regimes. *San Luis Obispo, CA. Spring/Summer 2000.*

	Crop Development			
Soil management program	Number leaves/plt.	Plant Diameter cm.	Number Flowers/plt	Number Runners/plt.
Organic Bare-root	7.10a	21.9a	3.93ab	1.9b
Organic Plug plant	7.57a	20.8a	4.03a	0.7b
Telone/CP Bare-root	7.53a	21.8a	4.00a	6.9a
Telone/CP Plug plant	5.57a	20.2a	2.73b	0.5b
Iodomethane/CP Bare-root	5.97a	20.3a	3.83ab	5.9a
Iodomethane/CP Plug plant	8.00a	21.7a	3.93ab	0.5b
Methyl Br/CP Bare root	6.37a	21.0a	3.60ab	6.0a
Methyl Br/CP Plug plant	6.23a	20.8a	3.57ab	2.5b

Means followed by same letter are not statistically different, Duncan's new multiple range test, P>0.05.

Weed Management

Weed populations were managed differently between the chemical and organic treatment plots. The opaque plastic allowed for good weed control between plants, however, the crop was delayed at least two to three weeks in harvest from the use of this technology. In-furrow weed management was performed by tractor cultivation on three occasions during the production season in the chemical fumigation plots. In the organic plots this was not possible due to the mulched hay present in furrows. In this case, volunteer wheat and occasional weeds required mowing by a hand weed whacker, which was somewhat laborious and time consuming, although effective. Weeds developing next to strawberry plants in the plastic mulched rows were hand weeded across all plots, timed, and sorted according to species present. The data were similar between treatments and indicate that if bed fumigated, these alternative fumigants are equivalent to the methyl bromide standard.

Data are presented for plot weeding requirements by experimental treatment in Table 2. While previous studies by this and other authors have shown significant reductions in weeding requirements with preplant soil fumigation, these plantings utilized opaque plastic mulch among all treatments, and therefore, weed populations had minimal impact on growing costs. All soil treatments, therefore, had statistically similar hand weeding requirements. Numerically, however, the methyl bromide standard and iodomethane treatments had the lowest costs for weeding. The predominant weed species among all plots were *Malva*, Filaree and various grasses.

Table 2. Weeding requirements in 4-soil management and two transplant strawberry production systems. *San Luis Obispo, CA. Spring/Summer 2000*

Weeding Requirements						
	Date of Required Weeding				Total [1]	Cost [2]
Soil Management Program	1/28	3/10	4/27	5/18	(Hrs./Acre)	($USD/Acre)
Organic Bare-root	1.7 a	25.2 a	23.5 a	4.0 b	54.4 a	505 a
Organic Plug plant	1.5 a	25.2 a	24.5 a	5.1 ab	56.3 a	522 a
Telone/CP Bare-root	0.3 b	25.3 a	22.0 a	5.1 ab	52.8 a	490 a
Telone/CP Plug plant	0.3 b	21.8 a	22.0 a	4.8 ab	49.0 a	455 a
Iodomethane/CP Bare-root	0.4 b	28.2 a	17.5 a	4.0 b	50.1 a	465 a
Iodomethane/CP Plug plant	0.3 b	28.2 a	23.4 a	7.5 a	59.5 a	552 a
Methyl Br/CP Bare-root	0.6 b	27.7 a	19.6 a	7.8 a	55.7 a	577 a
Methyl Br/CP Plug plant	0.5 b	18.0 a	14.9 a	7.7 a	41.1 a	381 a

Means followed by same letter are not statistically different, Duncan's new multiple range test, $P>0.05$
[1]Mar 10 Organic weeding is weed mower time, and also includes Feb 22 (3.25hrs.) for weed mowing in organic plots.
[2]Cost of weeding calculated by hours/acre at $9.38/hr contract labor and times rounded to nearest whole hour and dollar per acre.

Soil Microbial Biomass

Soil biomass data are shown for the various soil treatments in Table 3 below. As evidenced with statistical analysis by ANOVA, these data did not demonstrate trends in soil food web parameters among the various soil amendment programs. This included the Organic soil treatment, where large quantities of compost and Mycorrhizal inoculate were used. The VAM root colonization data were also unrevealing. Although increases in root colonization were expected from the early season application of VAM, roots did not show any corresponding increases in colonization by VAM at plant maturity late season.

Table 3. Soil food web data from late season sampling of bare root strawberry plots. *Summer 2000, San Luis Obispo, CA*

Soil Biomass Data				
Main Blocks Soil Management Program	Total Fungal biomass ugm/gm	Total Bacterial biomass ugm/gm	Ratio Active Fungal to Act. Bacterial ugm/gm	% Miccorrhizal Colonization of Root
Organic Program	154.7 a	36.7 a	0.730 a	16.7 a
Telone/Chloropicrin	150.3 a	17.3 a	1.193 a	13.0 a
Iodomethane/Chloropicrin	163.7 a	18.0 a	0.967 a	16.3 a
Methyl Br/Chloropicrin	156.0 a	19.7 a	1.120 a	23.3 a

Means followed by same letter are not statistically different, Duncan's new multiple range test, P>0.05.

Table 4 represents the average production by fruit type for the season from each soil management program and plant type. Data are expressed in number of marketable flats per acre and total weight produced from both fresh market and processing harvests. Production on and after May 27 was harvested for processing and includes bulk packed fruit of both quality types. At this period in the season, the Central Coast growers were harvesting exclusively for this market, and therefore the experimental harvest practices were changed to mimic commercial conditions. Overall, total harvests were somewhat low by commercial standards due to a shortened harvest season, reduced per acre plant population from the narrow bed culture, as well as the effect of the black plastic mulch used in this study, which favored the organic soil management program for weed control. Nevertheless, comparisons between treatments indicated significant differences among soil management programs. Compared to the methyl bromide/chloropicrin/bare-root plant treatment (standard grower practice), all soil management systems were statistically similar among similar plant type. That is, all bare-root planted soil systems, and all plug-plant soil systems were not statistically differentiated from one another within plant type. Numerically however, the Telone/CP and Iodomethane/CP systems out performed the Organic system by 8.9% and 12.9% respectively for bare root plants, and 19.3% and 11.4% respectively for plug plants.

Table 4 Harvest by fruit type and weight *San Luis Obispo, CA. Spring/Summer 2000*

Total Season Harvests by Fruit Type and Weight				
	Total fruit production by market		Total fruit weight	
Soil management program	Fresh K/ha	Processing K/ha	K/ha	% incr.
Organic Bare-root	3570 a	11480 b	15050 c	
Organic Plug plant	8075 a	29435 ab	37510 b	+149.2
Telone/CP Bare-root	3834 a	12514 ab	16348 c	
Telone/CP Plug plant	10273 a	33033 ab	43306 a	+164.9
Iodomethane/CP Bare-root	4047 a	12921 b	16968 c	
Iodomethane/CP Plug plant	10234 a	30205 a	40439 ab	+147.4
Methyl Br/CP Bare root	3712 a	11312 a	15024 c	
Methyl Br/CP Plug plant	7764 a	28527 ab	36291 ab	+141.5

Means followed by same letter are not statistically different, Duncan's new multiple range test, P>0.05.

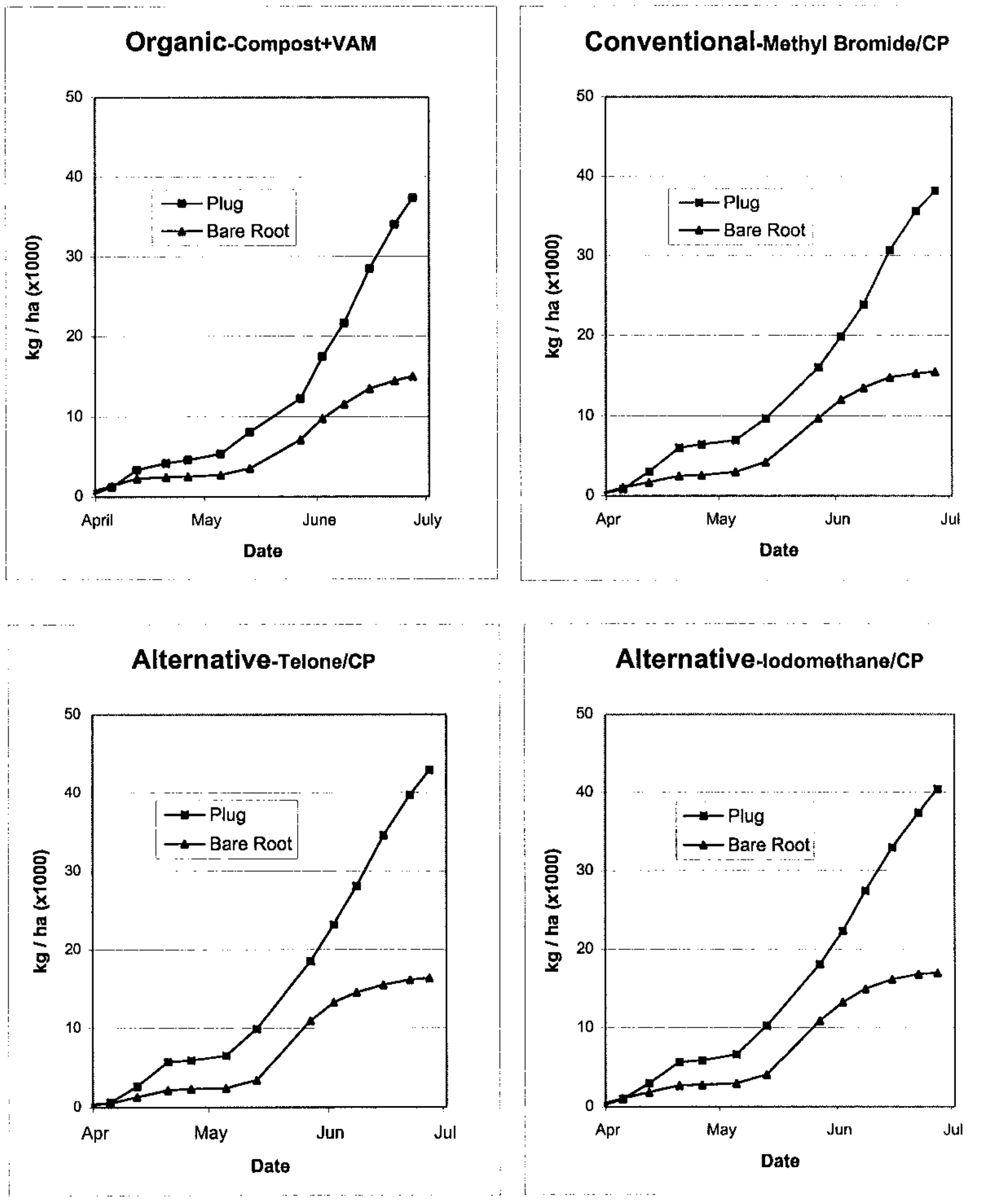


Figure 1. Cumulative yield for four soil management systems for conventional bare-root and alternative plug plants through the harvest period of the study. *San Luis Obispo, CA, Spring/Summer 2000.*

The major differences in yields were between plant types. In all cases, plug-plant treatments out-performed bare-root treatments by a significant margin. Figure 1 illustrates the seasonal yields from the four soil management programs for each plant type through the season. The harvest differences were apparent initially, and into the mid-season pickings. However, plug plants did not terminate as quickly as bare root plants, and continued to produce through the later part of the season. Further, these plants had fruit and flowers still present when the study was terminated in late June.

Summary and Conclusions

Field preparation and enhancement of planting material are the central aspects of this project. Among the soil conditioning systems, the organic system utilized the highest inputs for amendments. Here, the cost of compost and chicken pellets applied prior to listing beds was approximately $1000 at the rates used in this study. This was followed by weekly applications of fish emulsion that further added to the cost of plant and soil amendment. Also, while weeding requirements were similar to fumigated plots, this was the result of the black plastic mulch, which favored the organic system, but retarded growth and reduced overall yields across all soil management systems. In this respect, the fumigated plots could have used transparent plastic mulch, which would have resulted in earlier and higher yields, compared to the organic program.

Telone/chloropicrin and Iodomethane/chloropicrin performed very well with season yields and disease suppression overall. The cost of application of alternative fumigants was less than either methyl bromide/chloropicrin or the organic program, as a result of the use of reduced rate drip application technology employed. This technology proved to be very effective in controlling soil borne diseases, even in the clay soil of this site. In current dollars, at the rates used in this study, the cost of methyl bromide/chloropicrin flat fumigation is approximately $1400/ac., compared to $800/ac. for Telone/chloropicrin applied in this manner. The cost for Iodomethane at the rates used in this study is currently unknown.

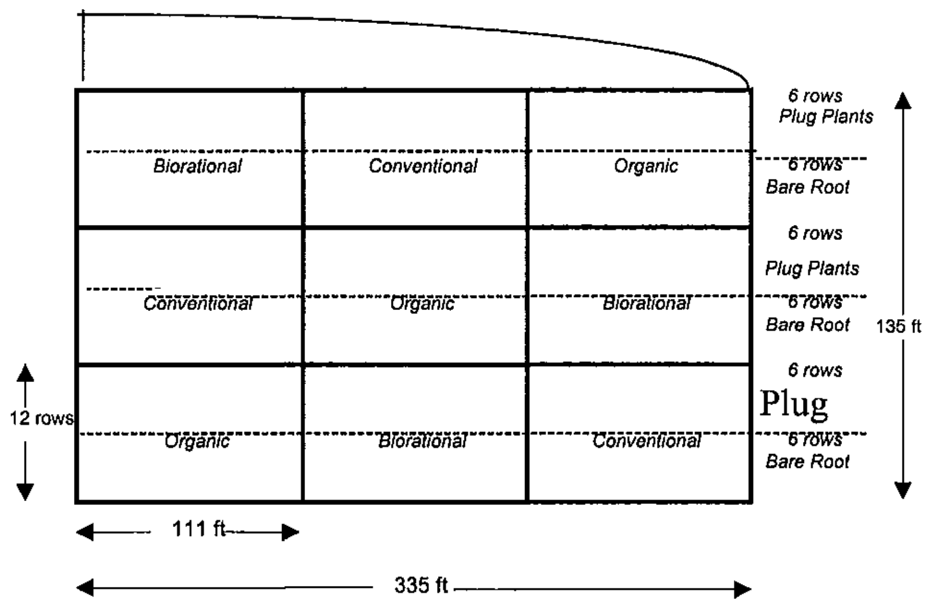
In this study, the use of plug plants had the greatest effect on yield. In each soil management system, the resulting fruit production was markedly higher than the bare-root transplants. The fruit was also of equal quality with respect to deformities and other market defects. It should be noted, however, that the cost of this technology is much higher than bare root plants. At current prices, plug plants sell for more than three to four fold that of bare roots of the same cultivar. The true cost of the technology, however, is the benefit derived from the earlier and higher yields obtained, minus the difference in direct cost of the plug plants. These parameters would vary from year to year, and most certainly be driven by the market prices early season.

With respect to Organic production, the yields derived from plug plants may overcome differences caused from parasitism by soil borne pathogens in non-fumigated soil. This is the result of plug-plants exhibiting less wounding and transplant shock at planting, which translates into increased vigor early season. Rapid early season growth establishes extensive fruiting crowns and a rhyzosphere that is developed in and around a nutritional matrix of potting soil. This system is ideal for water retention and root development. Roots so developed tend to inhibit opportunistic pathogenic organisms and may out-grow localized infections. Plug plant technology can also provide an ideal delivery system for economical use of Mycorrhizae and other beneficial organisms as used here. Incorporation of beneficial organisms in the planting plug at the greenhouse can uniformly distribute them across the field without the requirement for high rates to be soil applied. This could facilitate the use of these biocontrols in the future by reducing the rate per acre, and at the same time, improve their placement on the roots from the onset of the season

In conclusion, these results show that there are several existing alternatives to methyl bromide fumigation for California strawberries. The technology demonstrated here however, may require an increase in growing costs at the field level. In the case of alternative fumigants, the cost increases are relatively minor, and may be compensated for in other ways such as reduced rates and simplified drip chemigation methods. Plug plants can also provide high strawberry fruit production in non-fumigated soil, provided pathogen loads are low. The limitations here are the direct cost of weeding if transparent plastic is used, and the high cost of the plants themselves. In any case, growers will ultimately determine which of these alternatives are feasible for their individual operations in each distinct strawberry growing area of California.

Appendix 1

Figure. 1. Schematic of experimental field with locations of various soil management regimes. Each soil management system was planted into two plant types, bare root and plug plants. In the Alternative plots, these were split again into two alternative soil fumigants.



Appendix 2

Photograph. 2. Diagonal of experimental strawberry planting early season photograph. Organic plot in foreground.

Appendix 3

Photograph. 3 Comparison of bare root plants (left) with plug plants (right)1. Mid season growth in telone/chloropicrin main plot.

Appendix 4

Photograph. 4 Insectary border mix between main plots late season.